

Notes on mating behaviour and sex ratio control of *Tetranychus urticae* Koch (Acarina: Tetranychidae)

by

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Introduction

The two-spotted spider mite *Tetranychus urticae* Koch is an arrhenotokous species. Unmated females produce haploid eggs which develop into males, whereas mated females produce a mixture of haploid and diploid eggs which develop into males and females respectively, provided the eggs are viable. The sex ratio in the offspring of a mated female, therefore, also roughly indicates what proportion of the eggs has been fertilized. There is no "normal" sex ratio for spider mites. According to BOUDREAUX (1963) the sex ratio of the offspring of each female depends on the amount of sperm received during the mating act. Many authors have presented data concerning the sex ratio of different populations of *T. urticae* (GASSER, 1951). These data vary from population to population, though generally the number of females surpasses the number of males.

It has been noticed, however, for a number of *T. urticae* strains reared in the laboratory that the sex ratio remained rather constant over a large number of subsequent generations (OVERMEER, 1967; OVERMEER & HARRISON, 1969). This would mean that the ratio of the total number of eggs that are fertilized, against those which escape fertilization is rather fixed within these populations. The way in which the sex ratio is controlled is not known but OVERMEER and HARRISON (1969) found some indication that the control mechanism is mainly inherited via the female.

The present paper deals with observations on the mating act of *T. urticae* in order to throw some light on sex ratio control. It was investigated what relationship might exist between time spent in copula and the sex ratio of the offspring.

A spider mite female can mate several times with different males, but generally one mating is sufficient for the total production of diploid eggs (BOUDREAUX, 1963; HELLE, 1967). The behaviour of the mites during first and second matings was studied and also the effect of a second mating.

Material and Methods

Spider mites of the so-called Sambucus strain of *Tetranychus urticae* Koch were used for the experiments and observations. This strain has been in culture on bean plants in the laboratory since 1961. When a sample of randomly taken adult females is allowed to deposit eggs over a period of 24 hours, the ratio diploid eggs: haploid eggs is between $2\frac{1}{2} : 1$ and $3 : 1$ (OVERMEER, 1967).

The following method was used to study the transfer of sperm from the male to the female during the mating act. Freshly emerged females and males were placed together on a detached bean leaf fixed on wet cotton wool. The animals were allowed to mate over a limited period, namely 10, 20, 30, 60, 90 or 120

Table 1. Relationship between time spent in copula and sex ratio of the offspring of *Tetranychus urticae* (*Sambucus* strain)

female no.	time spent in copula	number of eggs deposited over 7 days	egg mortality	sex ratio offspring	
				♀ ♀	♂ ♂
1	3'37"	62	0	49	13
2	3'25"	65	3	42	20
3	3'20"	80	1	61	18
4	3' 6"	62	2	45	15
5	2'55"	49	4	32	13
6	2'35"	66	0	50	16
average values	3' 9"	63.9	1.6	46.5	15.8
7	120"	80	0	57	23
8	120"	49	4	31	14
9	120"	51	0	39	12
average values	120"	60	1.3	42.3	16.3
10	90"	61	2	32	27
11	90"	65	1	41	23
12 (+)	90"	—	—	—	—
average values	90"	63	1.5	36.5	25
13	60"	40	0	26	14
14	60"	66	0	41	25
15	60"	69	4	44	21
average values	60"	58.3	1.3	37	20
16	30"	68	0	35	33
17	30"	63	0	27	36
18	30"	59	14	0	45
average values	30"	63.4	4.7	20.7	38
19	20"	50	0	10	40
20	20"	60	1	11	48
21	20"	44	0	9	35
average values	20"	51.3	0.3	10	41
22	10"	39	0	2	37
23	10"	61	3	1	57
24	10"	41	0	0	41
average values	10"	47	1	1	45

seconds after which the males were removed from the females with the aid of a needle. The females involved were transferred to separate leaves. Other males were allowed to mate undisturbed with young females. After mating had finished the time spent in copula was noted down, the male was removed and the female transferred to a separate leaf. All mated females were given the opportunity to deposit eggs over a period of 7 days and the offspring of each female was examined as for its sex ratio.

To study the effect of a second mating 30 females that had mated once were placed on a detached bean leaf together with 100 freshly emerged males. The females had mated undisturbed the day before and the time spent in copula ranged between 2 min. 50 sec. and 3 min. 15 sec. The females were carefully watched and when a second mating had occurred they were separately transferred to other leaves. The males that had been involved were removed. The time spent in copula was noted down. If this had been less than 20 seconds both female and male were removed. Observations on the behaviour of the mites were made. After six hours of watching the experiment was stopped. A sample of females that had not mated a second time was also transferred to other bean leaves, each female separately. The females were given the opportunity to deposit eggs over a period of 7 days and the sex ratio of each offspring was determined.

Results

Data concerning the sex ratio of the offspring of females that had mated over various periods are given in table 1. These data all concern first matings.

Table 2 shows the results after two matings. Results are presented only when the second mating lasted more than 20". Data concerning the sex ratio of the offspring of a sample of females that refused to mate a second time are also presented. A duration of 3 minutes is generally assumed for all first matings.

Table 2. Relationship between time spent in copula and sex ratio of the offspring of *Tetranychus urticae* (*Sambucus* strain)

female no.	time spent in copula		number of eggs deposited over 7 days	egg mortality	sex ratio offspring	
	1st mating	2nd mating			♀ ♀	♂ ♂
25	3'	+ 2'	71	3	47	21
26	3'	+ 1'52"	41	0	31	10
27	3'	+ 60"	41	0	29	12
28	3'	+ 60"	77	1	58	18
29	3'	+ 50"	67	0	49	18
30	3'	+ 45"	60	1	51	17
31	3'	+ 36"	63	0	47	16
32	3'	+ 31"	75	0	55	20
33	3'	+ 30"	66	1	49	16
34	3'	+ 0	67	1	45	21
35	3'	+ 0	77	0	62	15
36	3'	+ 0	73	0	55	18

It appeared that most of the females were not willing to copulate again. Moreover, the females did not seem to be very attractive to the males. During the period of 6 hours 14 matings occurred and 5 of them were of short duration, *viz.* 5 tot 10 seconds. Sixteen females did not mate a second time. Moreover, it should be mentioned that second matings differed very much from first matings with respect to the behaviour of the females, at least nearly in all cases.

The females were unquiet when mating for the second time and in many cases interruptions occurred once or twice during the mating act. The abdomens of the partners then lost contact for a very short moment, *viz.* less than half a second. However, mating as such went on after contact was restored. Only in the case of 3 minutes + 2 minutes no interruptions were observed. The female did not noticeably try to end the copulation.

Discussion

The data presented in table 1 and table 2 indicate that a first mating lasts approximately 3 minutes at 25° C. The sex ratio of offspring of a female that has mated once was about 3 ♀♀ to 1 ♂, measured for the offspring produced over the first 5 days. Values were found ranging between 42 : 20 and 62 : 15. It appeared that within 10 seconds already a certain amount of sperm was transferred to the female, which fertilized a small proportion of the eggs. Apparently, ejaculation takes place nearly immediately after the onset of mating. The number of fertilized eggs increased when the duration of the copulation was longer. Presumably, there is a continuous flow of sperm from the male to the female during the time spent in copula. The amount of sperm transferred determines the sex ratio.

After a period of approximately 3 minutes the copulation is normally ended. It is not known what fact causes the end of the copulation. It may be that the male is not able to supply any more sperm at that time or that the female is saturated in some way. Therefore, it was considered interesting to study the effect of a second mating, with respect to the sex ratio of the offspring. However, in no case the sex ratio appeared to exceed 3 : 1 significantly. Even females which had mated successively over a period of 5 minutes did not show an increased sex ratio in their offspring.

The results presented in table 2 and the observations made on the behaviour of the mites during the second copulation suggest that a second mating has no or little effect after a successful first mating. Probably, the male is not or hardly able to bring sperm into the female during the second mating. This could explain the interruptions that occur during the second mating. As mentioned before in the case of the female that mated successively over a period of 3 and 2 minutes no interruptions were observed. It remains questionable of course whether the first mating was successful. The small number of observations made on mating of *T. urticae* do not give enough information to make general statements. However, it seems likely that the female accepts only a certain amount of sperm during mating and is saturated then for some time. It is possible that she is not able to take any more sperm at least for a certain period after a successful first mating.

It is assumed that the sperm is transported to the ovaries and that the immature

oocytes in the ovaries fertilized (BEAMENT, 1951, HELLE, 1967). The amount of sperm that arrives there presumably determines the chance that eggs are fertilized or that they escape fertilization, thus controlling the sex ratio.

It will be clear that male offspring is guaranteed only, if a female accepts a limited amount of sperm. It is necessary that some eggs will escape fertilization. Natural selection will act against those females that allow all their eggs getting fertilized, but also against those females that produce relatively little female offspring. In case of the Sambucus strain a sex ratio that approaches a value of 3 ♀♀ to 1 ♂ seems the most favourable. This means that on the average a female of the Sambucus strain accepts an amount of sperm that will fertilize about 75 % of her eggs.

Summary

The effect of different duration of the copulation on the sex ratio of the offspring of *Tetranychus urticae* Koch (Sambucus strain) was studied. Increase in duration resulted in increase of the female offspring up to a sex ratio of approximately 3 ♀♀ to 1 ♂. A sex ratio of 3:1 was generally found when copulation between two freshly emerged individuals was not disturbed. A second mating after a successful undisturbed first mating did not measurably affect the sex ratio of the offspring.

The behaviour of spider mites during first and second matings was studied also.

References

- BEAMENT, J. W. L., 1951. The structure and formation of the egg of the fruit tree red spider mite, *Metatetranychus ulmi* Koch. *Ann. appl. Biol.* 38: 1—24.
- BOUDREAUX, H. B., 1963. Biological aspects of some phytophagous mites. *A. Rev. Ent.* 8: 137—154.
- GASSER, R., 1951. Zur Kenntnis der gemeinen Spinnmilbe *Tetranychus urticae* Koch. *Mitt. Schweiz. ent. Ges.* 24: 217—262.
- HELLE, W., 1967. Fertilization in the two-spotted spider mite. *Ent. exp. appl.* 10: 103—110.
- OVERMEER, W. P. J., 1967. Genetics of resistance to tedion in *Tetranychus urticae* C. L. Koch. *Archs. Néerl. Zool.* 17: 295—349.
- OVERMEER, W. P. J. & R. A. HARRISON, 1969. Notes on the control of the sex ratio in populations of the two-spotted spider mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) *N. Z. Jl. Sci.* 12: 920—928.

Miller, N. C. E., *The biology of the Heteroptera*, 2nd (revised) edition, 1971. E. W. Classey LTD, Hampton Middlesex England, 206 pp, 77 figs, 5 pls. Prijs (gebonden): £ 4.50.

In het eerste deel, het algemene gedeelte, van dit boek, wordt in het eerste hoofdstuk een lijst gegeven van alle families en onderfamilies der wantsen (Heteroptera). Verder komen enkele algemene aspecten van de biologie van deze insekten aan de orde: de ontwikkeling van ei tot imago, de vorm en functie van de poten, de stridulatie, de natuurlijke vijanden en de binding aan zoogdieren en vogels.

Het tweede deel van het boek geeft per familie en onderfamilie de meest belangrijke en opvallende morfologische kenmerken, biologische bijzonderheden en verspreidingsgegevens. Van elke familie wordt de belangrijkste literatuur opgegeven en tevens wordt van iedere familie tenminste één vertegenwoordiger afgebeeld.

Voor hemipterologen maar ook voor alle andere entomologen die in de biologie en de systematiek van de wantsen geïnteresseerd zijn van harte aanbevolen. — J. P. DUFFELS.